USDA Attachment A

Cooperative Effort to Provide Technical Assistance in Developing Countries for Processing Low-cost Nutritious Foods

Final Report

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Cooperative Effort to Provide Technical Assistance in Developing Countries for Processing Low-cost Nutritious Foods

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1.0.0 INTRODUCTION

1.1.0 Project Scope

AID/ST/N has an objective of alleviating hunger and improving the nutritional status of the poorest populations in developing countries. Their programs to achieve this objective have focused on a wide range of activities, recognizing both the scope and complexity of the problems which exist. Many of their programs have been directed toward maternal and child nutrition since these populations are often the most vulnerable and they represent the greatest opportunity for high impact interventions.

To assist AID/ST/N, the USDA/OICD Food Technology Branch has evaluated and transferred food technologies which could help alleviate hunger and malnutrition of vulnerable groups in developing countries. Funding for these activities came from AID/ST/N and have been in existence since the 1960s.

To expand the effort in the area of food extrusion and other processing technologies, the USDA/OICD developed cooperative working arrangements with Colorado State University because of its extensive research, teaching and public service programs in the area of food extrusion and the role that this important food process plays in producing nutritious and acceptable low-cost foods from a variety of raw food ingredients. Several key faculty reside at the University who are

internationally acknowledged as world experts in food extrusion and nutrition because of their extensive industrial and academic experience. Specifically, Colorado State faculty and staff provided technical assistance on food processing technologies to make low-cost nutritious foods emphasizing the manufacture of weaning foods using low-cost extrusion cooking (LEC).

Cooperative working relationships between Colorado State University and the USDA/OICD Food Technology Branch have existed since 1974 through September 1989. Over this 15-year period, funding from AID/ST/N and other sources have augmented and utilized University capabilities to assist the transfer of food processing technologies suitable for the developing country environment. Specifically, AID/ST/N funding for the project provided through the USDA has amounted to $2,862,737 with matching of $189,822 from University sources of the AID/ST/N funding, $353,133 was for equipment and $514,333 for subcontracts and consultants.

This report chronicles all the activities undertaken during the cooperative efforts between Colorado State University and USDA/OICD Food Technology Branch directed toward objectives of AID/ST/N. Brief summaries of the projects are provided below with reference made to comprehensive reports which document individual project activities. Copies of the technical and nutritional reports submitted during the course of the project are available through interlibrary loan at the following address:

Morgan Library
Interlibrary Loan
Colorado State University
Fort Collins, Colorado 80523
(303) 491-1868

A final report with chronicles of the project is available and title: "Final Report: Food Technology for Development Project;" RSSA STB 0831 R-AG 4207, 1969-1989. Office of International Cooperation and Development, United States Department of Agriculture. The above document is available from

A.I.D. Development (mailing address)
Information Center
(Library) Room 105, SA 18
Washington, D. C. 20523-1801

A.I.D. Development (location)
1601 North Kent Street
Room 105
Arlington, Virginia
(703) 875-4818

and

National Agricultural Library
Special Collections Section, USDA
10301 Bolt Blvd.
Beltsville, Maryland 20705

1.2.0 Colorado State University Capabilities

A pool of faculty and staff reside in several departments which possess expertise in research on nutritious foods and processing. The University prides itself on the fact that interdisciplinary activities of the type represented by this program in food extrusion and nutrition are easily accommodated and promoted without the typical interdepartmental barriers that exist at many universities. The result of this interdisciplinary effort has been an exceptional record of accomplishment.

Through Cooperative working arrangements, USDA/OICD has functioned closely with and benefitted from several faculty and the facilities existing at Colorado State University, where the extensive program in food extrusion and processing and related areas of human nutrition involves 11 faculty and research expenditures of approximately $450,000 per year from all sources. Additionally, there are approximately 15 graduate students

who are pursuing topics that involve extrusion and/or its nutritional implications. Only some of these faculty and students have worked on the USDA/OICD and AID/ST/N projects, but the existence of this large group has provided important backup and support. Specific details of the totality of the research topics and its faculty are chronicled in the research bulletins of the Department of Agricultural & Chemical Engineering (ACE) and the Department of Food Science & Human Nutrition (FSHN), which are attached. These can be summarized as follows:

Researcher, Department	Research Topics
1. Judson M. Harper, ACE	Rheology of biopolymers, extrusion cooking of starch and protein, modeling food extrusion processes, manufacture of low-cost extruded foods, rice bran stabilization
2. Ronald E. Tribelhorn, ACE	Food extrusion systems, low-cost food processing systems, rice bran stabilization
3. Vincent G. Murphy, ACE	Food rheology and extrusion technology, grain dust extrusion, thermal vitamin loss
4. Bruce E. Dale, ACE*	Biomass utilization including extrusion pretreatment
5. M. Nazmul Karim, ACE	Control of extrusion processes
6. James C. Linden, ACE	Biochemical engineering and fermentation
7. G. Richard Jansen, FSHN	Protein-energy and lactation, low-cost extruded foods, nutrient requirements,

	nutrient loss during extrusion, international nutrition
8. Joseph A. Maga, FSHN	Effect of extrusion on digestibility, extrusion of whey/cereal blends, soy/dhal analogs, hydrocolloids in extrusion, potato extrusion, flavor
9. Klaus J. Lorenz, FSHN	Functional and nutritional evaluation of cereal grains
10. John N. Sofos, FSHN	Destruction of spores during extrusion
11. Erik G. Thompson, CE (Civil Engineering)	Finite element modeling of flow through extrusion dies

*Currently at Texas A & M University.

To support these researchers and their teaching and research programs, the University has developed extensive research laboratories and facilities. These include a 1,500 square foot agricultural processing laboratory which contains full-scale equipment including three low-cost extruders and the necessary ancillary grain cleaning, dehulling, grinding, preprocessing, and drying equipment to allow for research and demonstration of the process. In addition, there is a 500 square foot experimental laboratory with a variety of small-scale extruders which are used for basic work. Equipment in these combined laboratories is valued at $250,000. Besides the engineering processing laboratories, there are modern food science and human nutrition laboratories. The value of this food science and nutrition facility is in excess of $3.0 million.

A unique feature of the Colorado State University is the large number of its faculty who have had industrial experience prior to their academic

careers. In the few cases where this relevant experience wasn't present, the faculty have been extensively involved with industrial consulting. These collective experiences have been an essential ingredient in research and development activities which have spanned the spectrum from laboratory benchtop to technology transfer to technical assistance to food processing operations. Where gaps in experience existed, Colorado State has hired consultants with relevant backgrounds to provide USDA/OICD and AID/ST/N the totality of resources required.

1.3.0 International Dimension of Colorado State University

Colorado State University is the Land-Grant institution in Colorado and has a long history of education, research and outreach. It is also a leader in international technical assistance. In FY 1987-88 this past year, Colorado State ranked second in the nation among universities working on USAID programs with 14 contracts and subcontracts funded by AID totaling $6.7 million. Colorado State faculty are helping people to help themselves in a dozen or more countries in the Third World. The first university in the country to sign such an agreement in 1983, Colorado State University will sign a second phase Memorandum of Understanding to work together with USAID in October 1989. Recent enrollment of foreign students was 927, representing over 100 countries. Colorado State is considered a national leader in community programming with these students and its staff are called upon as consultants for this type of activity. Last Fall, Colorado State University established its own study abroad program. Additionally, approximately 180 students study abroad on a variety of programs annually. Colorado State has the highest percentage of undergraduate students

volunteering for the Peace Corps of any university in the United States, which is strong evidence of its commitment to international programs. This outstanding record of international commitment and programs makes Colorado State an ideal partner for collaborative work directed toward addressing problems of world hunger.

1.4.0 Historical Development of Activities Under the Cooperative Agreement

Collaborative work on the application of food processing technology for the local production of supplemental foods which could replace Title II blended foods began with the initiation of a contract between Colorado State and the USDA/OICD in July 1974. The first activities focused on analyzing low-cost food processing systems for cooking mixtures made from locally grown cereal and legumes in order to stimulate the use of agricultural crops such as soybeans, provide employment, initiate the development of food processing factories, and produce hygienic and nutritious products at low cost which could aid mothers and children.(R2) These efforts indicated that extrusion cooking would be the most effective means of accomplishing these objectives, with roasting technologies being another promising approach.(R4)

Next, the work turned to examining extrusion cooking alternatives. To fit the developing country environment, it was determined that these extrusion systems have low initial capital cost, be relatively simple to operate and maintain, be capable of effectively processing and cooking a wide variety of raw cereals and legumes, produce hygienic and nutritionally rich foods, and have relatively low production capacity (<0.5 MT/hr). Typically, extrusion systems used in the developed world for the production

of convenience foods are of large capacity, quite expensive to install and require sophisticated ancillary equipment. Research efforts focused on simple Low-cost Extrusion Cookers (LEC) originally developed to heat-process soybeans for improved animal feeds. LEC fit most of the criteria necessary for developing country applications, but their capabilities as well as limitations for producing human food supplements needed to be documented.(R2,4,6) Initial efforts at Colorado State focused on determining operational aspects of LEC.

Once suitable LEC were found, tested and documented, the project directed efforts to transfer the technology. Initially, Brady extruders were donated by Fox-Brady, Koehring Farm Equipment Division and placed in India, Kenya (East Africa) and Guatemala (INCAP). Their purpose was to provide interested parties in the public and private sectors access to the technology so that products made from locally available raw materials could be developed and tested. Colorado State provided on-site assistance to groups in Kenya and Guatemala to aid this technology transfer process. Although the extruder could be used to produce sample products, it was quickly realized that both pre- and post-processing equipment was necessary to achieve continuous operating status suitable for producing human food. The next stage of the work focused on designing and installing demonstration plants in developing countries. Suitable demonstration sites were found in Sri Lanka, Tanzania and Costa Rica. Each was considerably different, which strengthened the scope of the demonstration, and each had an initial outlet for the product through the replacement of Title II commodities which were being phased out by Food for Peace. Plants were designed, equipment purchased and installed, personnel trained, and the

plants operated on a commercial scale. These demonstrations consisted of documenting capital and operational costs and the productivity of the plants. Commercial marketing of the product was undertaken and documented in some cases.

Following the demonstration work, the project moved into a full scale technology transfer phase. Activities such as international workshops, papers, reports, newsletters, seminars, plant designs, feasibility studies, training materials and courses were undertaken. These have raised considerable interest in the project and stimulated the need for technical assistance to a number of countries or companies interested in applying the technology to a variety of food processing and commercial marketing situations.

In addition, Colorado State University has studied the heat-processing of full-fat soy flour for the fortification of cereal blends, the extrusion stabilization of rice bran to increase its storage stability and so improve its potential as a feed stock for the solvent extraction of edible rice bran oil, precooking cereals for incorporation into improved ORT (oral rehydration therapy) solutions, production of energy/calorie- and nutrient-dense foods to facilitate the rehabilitation of children suffering from diarrheal disease, and the direct texturization of whole raw soybeans to produce a vegetable product with meat-like characteristics. The results of these studies have been documented in reports and papers.

2.0.0 SUMMARY OF ACTIVITIES

2.1.0 Evaluation of Low-cost Cooking/Processing Alternatives

An engineering evaluation of alternative processing systems which have been used to process nutritious food mixtures for use as weaning foods was undertaken.(P10) Specifically, the systems evaluated were:

1. Extrusion processing
2. Roller drum drying
3. Spray drying
4. Baking
5. Milling
6. Roasting

Each process was analyzed as a separate technology having a complete processing system so that comparison could be made on a similar bases. Production capacity, capital costs, operating costs, type of food products produced, use of locally manufactured as opposed to imported equipment, maintenance costs, energy utilization, processing moistures, skill to operate the systems, and sanitation requirements were used to evaluate and compare the systems.

Based on the above criteria, the food extruder and roaster were found to offer significant potential as appropriate processing systems for the central processing of nutritious foods. In large measure, this conclusion resulted from the fact that these processes could cook food materials with little or no added moisture, thus eliminating the expensive drying step necessary to render them shelf-stable. Furthermore, these processes used a

larger fraction of locally produced equipment which reduces cost and increases maintainability in the developing country environment.

The dry processing benefits were evidenced in low-cost finished products. Although the dry processing systems placed greater limitations on the types of finished products, which are mainly precooked instant powders that can be reconstituted with water to form gruels, drinks or soups, or used in combination with other ingredients to produce traditional foods; these types of foods make up a significant portion of the diet in developing countries. Specific details of this study and the results are contained in several documents.(R1,2,4,6,7,9, 10; P1,3,4,5,6,7,8,9,13)

2.2.0 Evaluation of Capabilities and Limitations of LEC

A major portion of the project effort was channeled towards evaluating and determining the capabilities and limitations of various extruders as candidates for low-cost units. Extruders evaluated were:

1. Brady Model 260
2. Insta-Pro Models 500 and 2000
3. Anderson Model 4.5"

Each of these units were evaluated for capability to process blended raw materials into precooked, nutritional and functional food products suitable for weaning-aged children.

2.2.1 Pilot Plant

To evaluate the extruders, a pilot plant was established at the Agricultural Engineering Research Center, Colorado State University.(R15) The pilot plant has four storage tanks for different raw materials, a

proportioning mill to mix and pregrind products before extrusion, the extruders, and an array of conveying, milling and post-treatment equipment to prepare the products for evaluation as weaning foods and other uses. The plant also has equipment to decorticate soybean and other grains.

Raw materials which were used infrequently or for a one time test run were stored in sealable containers until used. The pilot plant is housed in a 1,500 square foot building dedicated totally to extrusion processing.

Necessary instrumentation was available at the pilot plant to measure and define critical parameters for extrusion. Power could be measured electrically through an amperage meter or strain gage dynamometer. Water and steam inputs had devices to measure flow continuously. All other measurements were made manually or through precalibration of operating devices such as feeders.

The pilot plant was used effectively to test the various extruders, to develop food prototypes and as a means to demonstrate the potential of LEC to manufacture specific food items to private industries and government institutions.

2.2.2 Raw Materials Tested

An array of raw materials were tested to define the operational range of each extruder. A majority of the materials were tested in the Colorado State pilot plant; however, added experience has been gained through the technology transfer part of the project when in-country tests were conducted using the extruders. The majority of the in-country extruder testing used combinations of materials which resulted in nutritious and acceptable formulations directed toward local tastes. Raw materials tested in the extruders were:

Cereals	Legumes	Oil Seeds
Corn	Chickpea	Soybean
Rice	Dry beans	Cottonseed
Sorghum	Mung bean	Peanut
Millet	Cowpea	Coconut
Cassava	Pinto Beans	Rice Bran
Wheat	Kidney Beans	Oat Bran
Oats		

2.2.3 Extruder Testing

Each extruder was tested to determine its capabilities and limitations using various materials and combinations of the materials listed above. Data recorded for each test consisted of machine settings, water addition, power consumption, throughput, raw material granulation, moistures, etc., to accurately quantify the operation of each extruder. From the test results, several general observations about LEC can be made.

1. LEC are capable of making satisfactory products to use for weaning food supplements and other purposes.
2. Control of LEC operating in the moisture range of 15-20% is best when the fat level is between 5-20%. Operation outside of this range normally results in surging or plugging of the extruders.
3. Precisely shaped extrudates, for purposes of making snack foods, cannot be consistently made in most cases due to the difficulty in controlling operational parameters of the LEC. Also, the physical design of dies on these machines prevents the units in most cases from making precisely shaped products.

4. Particle size of input materials plays a key role in the operation and quality of the products made. Typically, LECs require larger particle sizes which, in turn, cause some nonuniformity of the extrudates.
5. The dry nature of the material passing the extruder plus the autogenous characteristic of the extruder causes more wear of moving extruder components than if the products were extruded at higher moistures.
6. LEC require high energy inputs to process raw materials; however, they do not require drying after extrusion. This fact makes LEC an economically attractive alternative where cooking is the primary objective.
7. For most blended foods, specific power consumption averaged about 0.1 hp-hr/lb (0.06 kw hr/kg) for all extruders. This level of energy addition is common for discharge temperatures between 150-170°C.
8. All extruders were tested using cereal, cereal/soybean combinations and soybean and were found to effectively cook these materials. It was also determined that some control of product functional characteristics was possible by varying extrusion moistures and temperatures.

A number of extruder specific observations are listed below in separate sections.

2.2.3.1 Brady Model 206

The Brady extruder is a self-contained unit and can be operated remotely with a power source capable of transmitting shaft power. The following are observations of its operation and testing.(R2,4,6)

1. The extruder is not capable of making precooked shaped snacks due to its die design.
2. Extrusion of 100% cereals is possible with 4-6% water addition; however, such operation requires the attention of an operator at all times.
3. Extruder components can be rebuilt or remanufactured with simple hand tools and welders. Some machining is required when remanufacturing or rebuilding some of the parts.
4. Operation of the Brady extruder is easily understood and grasped.
5. The extruder is the lowest cost of all LECs tested.
6. The output from the extruder is homogeneous and cooked satisfactorily for purposes of making blended foods.
7. The Brady is incapable of producing textured vegetable protein and precooked dry bean materials.
8. Routine maintenance cannot be performed while operating, requiring stopping the machine for these operations.
9. The Brady operates optimally in a moisture range of 10-14% for most combinations of raw materials used.
10. The Brady die opening can be adjusted during operation which gives considerable control and flexibility for changing temperature or raw materials without internal component reconfiguration.

11. The Brady is effective in stabilizing and agglomerating rice bran when using high quality bran.

2.2.3.2 Insta-Pro Extruders

Both the model 500 and 2000 units were tested in the pilot laboratory to determine their performance characteristics.(R2,4,6,9) The machines are built for plant operation and are not portable. Both units can manufacture shaped products and can process a slightly wider range of raw materials than the Brady. In addition:

1. Operation and control of the Insta-Pro extruders is accomplished through internal component configuration which requires shut down to change. This is not seen as a significant problem for most production situations unless multiple products need to be made and each requires relatively short runs.
2. The extruders tend to operate more effectively at higher moisture levels (12-18%) which at moderate extrudate temperatures could require drying. The model 500 tends to operate at the high end of this moisture range while the 2000 operates well at the lower end.
3. The extruders are capable of processing products such as textured vegetable protein with considerable modification to the normal operational parameters.
4. The Insta-Pro extruders are built for continuous operation having reasonably good metallurgy which increases the time between replacing and rebuilding parts.

5. Insta-Pro has improved their equipment considerably in the past years and now have a line of equipment that can meet the needs of a number of processing applications involving extrusion.(T1)
6. It is possible to make shaped pieces with the Insta-Pro extruder by carefully selecting machine components. These can serve as snacks or breakfast cereals.
7. Rice bran can be stabilized using either of the Insta-Pro extruders. Tests at Colorado State University using Insta-Pro extruders and three- to four-day-old bran indicated that bran can be agglomerated; however, the extrudate pieces tend to be somewhat friable in nature.

2.2.3.3 Anderson Model 4.5"

The Anderson extruder approaches the upper cost limit of the LEC definition. This extruder is very durable but requires considerably more ancillary equipment than the other LEC units investigated. The benefit received for the additional cost of the Anderson and the ancillary equipment is increased flexibility in types of raw materials and forms of product outputs.(R9,15) In addition,

1. It is possible to control the quality of the product more precisely with the Anderson to achieve the desired functional characteristics such as incorporation of product into water, smoothness and flavor of gruels.
2. Shaped extrudates suitable for snacks and ready-to-eat breakfast cereals can be made.

3. The extruder tends to operate most efficiently at moistures between 18-25% which requires product drying.
4. The extruder can also be configured appropriately to operate as a dry autogenous extruder for which product drying is not necessary.
5. Products made with the Anderson are homogeneous and well cooked.
6. The extruder is easily unplugged should an operational or electrical failure occur.
7. The extruder is a wet start-up and shut down unit and requires special cleaning and handling equipment.
8. The Anderson can stabilize rice bran and is capable of making agglomerated pellets of different sized diameters. Larger diameter pellets were judged to be more friable than the smaller diameters.

In summary, the testing conducted in defining the capabilities and limitations of each LEC machine characterized each extruder. Each unit has application divided toward specific products or processing needs, but care should be taken in selecting the appropriate unit so that product requirement and extrusion capabilities are matched. In most cases, it is recommended that each machine be tested prior to purchase to assure that any specific products or unusual raw materials to process can be extruded.

Documentation of all tests dealing with evaluation of these extruders may be found in various publications from the project.(R1,2,3,5,6,7, 9,10,15; T3,4,19,29,31,48,52)

2.2.4 Product Evaluation

Extruded products made in the pilot plant and during other applications of extruders in the project were evaluated for nutritional and functional characteristics to help define extruder utility. The effectiveness of LEC in making full-fat soybean flour (FFSF) was also evaluated with similar tests.

2.2.4.1 Tests Conducted

Standardized procedures, when applicable, were followed to test products made with the LEC units.(MR5,6) The primary goal for all tests was to measure the nutritional and functional characteristics and compare them with similar foods as documented in the ASCS standard specifications for Title II foods.(MR7) The following tests were used to evaluate and characterize the products made.

1. Proximate analysis (protein, fat, crude fiber, ash, moisture and carbohydrate).
2. Protein Efficiency Ratios (PER).
3. Physical Characteristics such as color, taste, particle size, etc.
4. Storage stability tests.
5. Functional tests such as viscosity and consistency of finished products when hydrated in hot and cold water.
6. Taste panel studies.
7. Incorporation tests to determine ability of material to go into solution.

8. Clinical studies to determine and guarantee the suitability of the food for feeding children.

9. Trypsin and urease tests to determine the degree of cook for soybean.

2.2.4.2 Proximate Analysis

Results from the proximate analysis confirmed the quality and the nutritional adequacy of various products.(R1,2,4,6,7,8,9,10,13,14,15; PB9, 10; P6,7,8,9) Products tested generally had a protein level of 12-18% and a caloric content ranging between 350-450 kcal/100 g of food product. Fiber levels were measured between 0-5% which met various international guidelines and nutritional recommendations for infants.

2.2.4.3 Protein Efficiency Ratio

Protein Efficiency Ratio (PER) was used to measure protein quality. Test results for each product were measured and compared with milk protein (casein) fed in the same study. Information on the test procedures and results are detailed in several documents.(R2,4,6, 9,10) The protein level and quality was greatest when a formulation contained both a cereal and legume. These data confirm the complementary nature of cereal and legume proteins when combined.

Products formulated and extruded using LEC were found to have weight gain characteristics similar to and in some cases better than casein indicating high protein quality. PERs were run mostly on CSB blends; however, tests were also conducted on other cereal/legumes or oil seed combinations as well as other products made in demonstration countries.

2.2.4.4 Physical Tests

Physical tests run on the LEC products included particle size distribution, color, density, etc. These tests were conducted to quantify physical characteristics of the extruded food and to formulate quality control standards for use in plants. Results were found to correlate with processing conditions and were within ranges set by the ASCS for Title II Foods.(S8,12; MR7)

2.2.4.5 Storage Stability

Both long term and short term storage tests were run on extruded products.(R2,4,6,9,10; S11,13,14) For most storage tests, processed materials were stored in jars (sealed and unsealed) in polyethylene bag material which was sealed and in other containers as specified. Containers and products were placed in three conditions; 0°C for control, normal room conditions of temperature and humidity (25°C, 20% RH) and the third in a high temperature-high humidity condition (32°C, 90% RH) for accelerated storage tests.

In general, it was determined that the blended food products were shelf stable for up to six months in polyethylene bags.(R4,6,10) Some products had as much as one year stability before significant rancidity or product quality losses were noticed. Products with a soybean component seemed to have more stability over time due to natural antioxidants in the beans. Samples made from 100% cereals were found to have the shortest shelf life which in some cases was only one or two months.

2.2.4.6 Functional Tests

Tests were conducted to quantify, as accurately as possible, product performance as it might be used by consumers. Viscosities of products when mixed with cold and hot water were measured using a Brookfield Viscometer and a Bostwich-type consistometer. Results showed a strong correlation between viscosity and degree of cook or processing temperature in the extruder.(R4,6,8,9,10,14,15) As processing temperature increased, the cold paste or hydration viscosity was higher for the Brookfield and the Bostwich consistency had a lower value.(R6) Because both tests correlated well with processing conditions, the lower cost and quicker Bostwich test was ultimately incorporated into the in-plant quality control procedures to measure on-line processing quality during operation.(S8,12)

In addition, viscosity tests were used to establish caloric density of foods.(R8,9,10) The amount of product that is required to give a specific viscosity with a constant amount of water allows the caloric density to be determined. Studies showed that through control of formulation and processing conditions, it is possible to modify the caloric density of blended foods.(R8,9,10)

2.2.4.7 Taste Panels

Taste panels were used to evaluate LEC products. The panels were trained for detecting properties such as rancidity, flavors, etc., and quantifying any differences detected in the products immediately after processing and after periods of storage. Results from these tests indicated that products were generally satisfactory.(R1,2,4,6,7,9,10)

2.2.4.8 Incorporation Tests

A test was devised to more accurately determine the ease with which the LEC products can be incorporated into water to form a gruel. This test was strictly subjective, but enabled evaluating the degree of lumping, smoothness of the mixture and degree of settling when the cooked extruded flours were mixed with water. It also helped predict consumer acceptance of the product by correlating processing conditions to functional performance. Generally, it was found that lumping, smoothness and settling correlated with processing conditions of temperature, moisture and extruder configurations.(R14,15; S13,14)

2.2.4.9 Clinical Tests

To better understand product quality and field performance of a product, actual tests were done feeding children these foods and measuring their response to the diet. Samples of CSB, sorghum blends and other foods were sent to Peru for clinical testing by Dr. George Graham of John Hopkins University. Results from these tests indicated that the CSB products, particularly those with low fiber levels, were satisfactory as weaning foods based on weight gain and nitrogen retention of children. Fiber contents higher than 1% were noted to cause minor intestinal irritation in children; however, this problem could not be traced totally to the fiber content.(R4,6,10) Extrusion cooking of sorghum was found to be particularly effective in increasing the digestibility of the resulting product when compared to conventional high moisture cooking typically used in developing countries.(MR10) These preliminary results could have a profound effect on food supplies in Africa.

2.2.4.10 Trypsin and Urease Activity

Measurement of the trypsin inhibitor and urease activity in products containing soybean has been used to indicate degree of cook. Tests conducted on blended products made with LEC and 100% soybean showed that a sufficient amount of trypsin inhibitor was destroyed in the extrusion process.(R1,2,4,6,9,10) Urease was destroyed before the trypsin inhibitor during processing making it a less valuable measurement.

2.3.0 Extruder Sites

One special element of the project was to promote use of the LEC in countries expressing interest and demonstrating a potential need for this technology. To assist in reaching this goal, extruders were made available, along with a portable diesel power unit, for groups and projects to use. All raw materials and any ancillary equipment to make the extruder operational was provided on site. Specifically, the extruder and power unit was made available to:

1. Demonstrate the LEC capabilities and limitations.
2. Assist potential users in developing products that could be made using the extruders.
3. Expand the operating data base for the extruders.
4. Further the transfer of the LEC technology.

Colorado State University provided an engineer to these sites to help set up the units, train personnel and demonstrate the units. The locations that this type of assistance was provided and the approximate amount of time expended in-country and in the United States are listed below.

1. Guatemala 3.5 man-weeks

2.	Guyana	4.0 man-weeks
3.	Thailand	2.5 man-weeks
4.	Philippines	2.5 man-weeks
5.	Indonesia	2.5 man-weeks
6.	Kenya	2.5 man-weeks
7.	Costa Rica	1.5 man-weeks

2.4.0 Demonstration Plants

As a part of evaluating the capabilities and limitations of the LEC, demonstration plants were designed and installed in strategic locations in the world. Plants were established in:

1. Sri Lanka
2. Costa Rica
3. Tanzania

It was the overriding goal of these plants to evaluate the suitability of the technology. Specific information on the various sites is given below.

2.4.1. Sri Lanka

<u>Background</u>

The Government of Sri Lanka (GOSL) in cooperation with CARE initiated an institutional feeding program in an effort to reduce malnutrition in that country. The project first imported Food for Peace, Title II foods which were repackaged and distributed through Maternal Child Health (MCH) Centers to infants and pregnant women country wide. This product was called Thriposha.

The GOSL and Care were interested in promoting indigenous processing to extend imported Title II foods which would expand the food distribution program to the MCH Centers. In addition, they were interested in starting a soybean production program to promote the growing and utilization of this product.

Local bakeries were first employed to bake a mixture of sorghum flour mixed with other ingredients such as oil, etc., which was reground and mixed with the imported Title II foods. After several attempts to make this food, it was determined that the capacity and capability of the local technology was not sufficient to achieve the intended goals and production needs of the project.

Concurrent with this activity, USDA/OICD met with CARE/New York officials to explore potential interest in LEC. CARE/NY suggested that LEC technology might be suitable for the Thriposha project in Sri Lanka. Based on this discussion, a visit was made by P. R. Crowley, May 1987, to Sri Lanka to explore potential use of LEC in the Thriposha program. It was determined that mutual interest in LEC existed within CARE and the USDA, therefore a project was developed.(T37)

Project Objectives

The Thriposha project set out with a three-phase plan which contained current and long-term objectives. The three phases were:

Phase I - Starting the Thriposha program by importing WSB from the United States and repackaging it for distribution.

Phase 2 - Initiating a substitution program of indigenous cereals to reduce the amount of WSB required. This phase included the

initial effort to bake indigenous sorghum and eventually the installation of an extrusion processing plant at Kundesale and later a new replacement facility in Ja-Ela.

Phase 3 - Implementing a program using 100% indigenous grains in Sri Lanka for the production of Thriposha. This phase included a large factory facility to produce 100% of the Thriposha requirements.

The three phases enabled the project to look at alternative processes including LEC. When LEC was selected, studies and discussions with key individuals led to a set of objectives for the production facilities installed in Kundesale and finally in Colombo. These objectives were:

1. Provide a processing facility capable of manufacturing one component of the baby food, Thriposha, from indigenous raw materials which would be blended with Title II foods.
2. Provide a facility to evaluate an LEC under production conditions.
3. Consolidation of all existing independent processing operations; CSB production, blending and packaging, into one facility in Sri Lanka.
4. Provide a facility with increased capacity to meet the goals of the Thriposha program for the next two years.

Methodology of Meeting Goals

Colorado State University provided key inputs to the project which helped to make the project and plant successful. Inputs of technical

assistance were provided throughout the fifteen-year involvement with the project and included:

1. Feasibility Studies (T37, F1)
2. Design and Construction Documents (T37,41,42; S15,16)
3. Training and Start-up Assistance (T37,43)
4. Troubleshooting and Backstopping (T38,39,41,42,44,46)
5. Nutritional Assistance (T40,45)

Results

An LEC plant was installed in Kundesale to process sorghum.(T37,38,39; R2,3,4) The extruded and ground sorghum was then shipped to the capitol, Colombo, for blending with the imported Food for Peace commodities before distribution. The extruded sorghum was later replaced by a corn/soybean mixture since sorghum availability was reduced and there was an effort to change the formulation of Thriposha to a corn-base product rather than wheat. After four years, the logistics of this processing scheme became too cumbersome, and the initial plant was moved and upgraded to a site in Colombo where all previously independent operations were consolidated. The consolidated plant has operated for approximately ten years with operating efficiencies exceeding 80% of potential processing time.

The facility housing all processing operations near Colombo in Ja-Ela has the capability to receive indigenous grain from the field and convert it to a precooked product. The plant has the capability to clean and destone raw grain materials, decorticate the grains, extrude, mill, and blend the cooked materials with other additives to make the Thriposha product.

To assure the installation was completed in a timely manner, several trips were made to Sri Lanka to coordinate with personnel.(T41,42,43) In addition, documentation was developed to define equipment in the plant and technical drawings were provided.(S15,16)

The plant as designed is a single-level facility suitable to accommodate additional processing equipment required to reach the goal of 100% indigenously grown and processed food. Complete details of the plant have been given in several documents.(R2,4,6,7,9,10; S15)

The effort and expense necessary to achieve consistent operation at the plant has been well documented.(R11) The specific capital costs for the Ja-Ela plant are summarized below.

Land	$ 27,968
Engineering and Technical Services	61,300
Building	283,779
Rail Siding	78,753
Equipment	304,347
Installation and Materials	31,119
Installation Salary	2,238
CARE Personnel	45,717
Furniture	1,231
Machines and Fixtures	430
Canteen Equipment	541
Total Cost Less Working Capital	$ 837,423

The plant began operation in January 1980. A method of evaluating LEC plant operations was developed and used for detailing the operations of the Ja-Ela plant including costs, yields and analysis of downtime.(R11) This

analysis revealed that costs to produce Thriposha were primarily associated with raw materials (89.6%), while other operational costs such as labor, utilities, etc., were the remainder of the production cost. During the most recent update, (January 15, 1981-January 14, 1982) Thriposha was manufactured for $0.465 per kilogram.

Levels of input during the 15-year project are summarized below.

1.	In-Country Assistance	44 man-weeks
2.	In United States	104 man-weeks
3.	Consultants	20 man-weeks

Ongoing Technical Assistance

Colorado State has continued to support the Sri Lanka project beyond the start-up period. Since the plant began operations, assistance to solve specific processing problems (T38,39,41,42,43,46), specific plant issues (T41,42,43,46) and nutritional problems (T40,45) has been provided.

In 1988, Colorado State provided a complete set of equipment specifications and engineering drawings to USAID/SL for the GOSL to expand extrusion processing capacity from 1 MT/hr to 3MT/hr. These documents were used to solicit tenders from various manufacturers and suppliers for installation of extrusion equipment and ancillaries in the plant. The design was intended to meet the plant requirements developed during a feasibility study (S16) which outlined details for expansion of the processing capacity in the plant. As of 1989, tenders had been accepted and a decision was pending on the awarding of a contract for the work. No additional specifics have been received concerning the latter activity at time of completing this document.

2.4.2 Costa Rica

Background

The Government of Costa Rica (GOCR) and CARE initiated a Soybean Production and Utilization project to promote agriculture in Costa Rica. To insure that a market for soybeans existed, an element of food processing was added. A feasibility study was conducted which identified LEC and roasting as two alternatives for processing products consisting of corn and soybean mixtures. With the processes identified, technical assistance was provided to design and develop cost estimates for a facility that could make low-cost nutritious foods.(T6) Funding for the processing portion of the project was provided through an Operational Program Grant (OPG) which ran for three years.

Tests were run on a Brady Crop Cooker to identify processing conditions necessary to produce a corn/soybean mixture to replace CSB and full-fat soybean flour (FFSF) to be used as a protein fortificant as called for in the OPG. Enough product was manufactured to use for preliminary acceptability studies in Costa Rica.

Since two appropriate processes were identified for making FFSF, the OPG called for the installation of a factory that would accommodate both the extruder and roaster. This installation would have permitted evaluation of both processes to make FFSF. Upon installation of the plant, both products were made on a limited basis. The extruded corn/soybean product was found to have limited acceptability and utility in the feeding programs that they were serving, necessitating a need to expand the range of products made in the plant. The demonstration of FFSF products was

limited to the extrusion process, and the roasting technology was never evaluated in the field due to a lack of interest.

The GOCR and CARE began a program to develop alternative products with assistance from the Centro de Investigaciones en Technologia de Alimentos (CITA) that were oriented to the needs of the school feeding programs they would serve. Due to these efforts and several technical inputs from Colorado State University, a total of nine different products were made by the plant and distributed to schools. These products included drink mixes (four different flavored Freschorchatas and one flavor Vitaleche), instant tortilla flour (Masarina), instant bean mixture (Frijolisto), and a rice based breakfast cereal. Feedback by the cooks and children in schools indicated that these products were acceptable and well received.

<u>Project Objectives</u>

The Costa Rica project had several objectives including:

1. To establish a manufacturing facility to produce low-cost nutritious foods and blended food supplements utilizing locally grown commodities to the greatest extent possible.
2. To manufacture a cooked soybean flour to be used as a fortificant in flours for bread making, etc.
3. To use the foods made in food distribution programs where they would serve as part of the diets of up to 500,000 children 0-12 years of age, pregnant women and lactating mothers.
4. To determine the economic feasibility of growing soybeans in Costa Rica for use as a raw material for making inexpensive nutritious foods.

The above goals were achievable by the installation of a processing facility located in Carridabat, San Jose, Costa Rica. The objectives of the processing facility were:

1. To provide a processing system to make nutritious foods which could be operated and maintained by local personnel.
2. To produce up to 2,000,000 pounds per year of CSB-type product and 600,000 pounds per year of FFSF.
3. To provide a demonstration unit to evaluate the differences and economics of processing FFSF using extrusion and roasting.
4. To provide a demonstration unit for groups and individuals in Central and South America.

Methodology of Meeting Goals

Colorado State University provided key inputs to the project which helped to make the project and plant successful. Inputs, provided over a ten-year period, of technical assistance by category are listed below.

1. Feasibility Studies (T6,7)
2. Training and Start-up Assistance (T10,11)
3. Troubleshooting and Backstopping (T8,12,13,14,15)
4. Nutritional Assistance (T9)

Results

The OPG enabled the purchase of equipment for the plant which had the capability to receive grain in bulk or bags and store it for short periods of time; capacity for cleaning and decorticating of the raw grains, blending and extrusion of the ingredients, milling, and blending of the finished extruded product with preprocessed products such as flavors, milk

powder, vitamins and minerals. The plant also had an indigenously manufactured semi-automatic packaging line to finish pack the product prior to distribution.

To assure the installation was completed in a timely manner, several trips were made to Costa Rica to coordinate with personnel (T6,7) and to provide technical inputs during installation and start-up (T10,11). Several follow-up trips were made to provide assistance in solving processing problems, product development and evaluations of the project.(T8,12,13,14,15) Complete details of the plant have been given in several documents. (R4,6,9,10)

Capital costs for the plant as installed are summarized below.

Engineering and Technical Services	$ 49,793
Building	146,754
Equipment, Installation and Start-up	220,926
Processing Equipment	215,137
Total Cost Less Working Capital	$ 767,071

Land for the plant was furnished by GOCR and therefore was not included in the overall costing for the plant.

The plant began operation in June 1979 and operated successfully over ten years when operations were shut down because the GOCR ceased the purchase of LEC-produced products and no commercial markets had been established as a fall back. The plant capacity was judged sufficient to meet the demand of the GOCR feeding programs during the course of the project. Some excess capacity existed which enabled development of the alternative products and evaluation of processes leading to plant improvements and changes during the life of the project.

A protocol evaluation was done (R12) to document the costs, yields and down times for the plant operating between the period October 26, 1981-October 25, 1982. The protocol evaluated the performance of the plant for the product manufactured most frequently and thus having the most processing and operational information; Freschorchata. From a cost perspective, 73.4% of the production costs were from raw materials while the remainder of the costs were due to labor, utilities and others inputs. During the evaluation period, Freschorchata was manufactured for $0.483 per kilogram.

Levels of input by Colorado State into this project during the ten-year period are given below.

1. In-Country Assistance 39 man-weeks
2. In United States 80 man-weeks
3. Consultants 4 man-weeks

Ongoing Technical Assistance

Colorado State University continued to support the Costa Rica project beyond the start-up period. Since the plant began operations, assistance has been provided to solve specific processing problems (T12,13, 14,15), specific plant issues (T8) and nutritional problems (T9).

Colorado State University has been cooperating recently with Compatible Technology Incorporated (CTI) who is currently considering potential redirections of the project. Specifically, CTI has served as the technical assistance group to arrange for a Wenger X25-SLB to be installed in Costa Rica. Current plans for this extruder are to create products

similar to those made with the LEC, but to sell them primarily in commercial and industrial markets.

At one point, the extruder was destined for installation at a site different from the existing LEC plant; however, the GOCR has requested this group to consider utilizing the existing plant and equipment. Activities are now underway to evaluate the request of the GOCR and to determine the most suitable site for the new extruder.

During the plant's operation over a ten-year period, it was the mechanism by which CARE and others believe the food requirements for various feeding programs in Costa Rica were successfully provided. In addition, the plant generated additional interest in extrusion which has led to a need for more sophisticated processing and the plans to install the Wenger extruder with its expanded capabilities.

2.4.3 Tanzania

Background

The Government of Tanzania (GOT), Tanzanian Food and Nutrition Centre (TFNC), and the United States Agency for International Development (USAID) initiated a supplemental feeding program which used Title II foods to feed between 200,000-250,000 children having differing degrees of malnutrition. Approximately 5,000 tons per year of Title II foods were imported and distributed to people by Catholic Relief Services. It was determined that this strategy did not cover the magnitude of the malnutrition problems where up to 50,000 tons per year of blended foods would be necessary to make an impact.

TFNC had a primary goal of reducing the incidence of malnutrition and was instrumental in advising the GOT on nutritional issues. TFNC learned about LEC technology and sent two people to participate in the Colorado State assisted start-up and demonstration of a Brady Crop Cooker, located in Nairobi, Kenya, where interest in the unit and the technology began. A request made by TFNC to USAID resulted in necessary assistance to help plan for installation of an extruder and ancillary equipment to make a baby food supplement from indigenous materials in Tanzania.

Objectives

A number of objectives for the Tanzanian plant and project were set during the planning phases.

1. To develope capability within Tanzania to extrude blended foods made from indigenous products to replace current Title II foods.
2. To allow National Milling Company (NMC) to manufacture commercial weaning foods to replace imported products, thereby reducing further drain in foreign exchange.
3. To provide a processing system that could be operated and maintained by local personnel to make nutritious foods.
4. To produce up to 5,000 MT/yr of CSB-type product.
5. To provide a demonstration unit for groups and individuals in the African regions.

Methodology for Meeting Goals

Colorado State University provided key inputs to the Tanzanian project, such as plant design and technical assistance during installation and start-up. Inputs of technical assistance are listed below:

1. Feasibility Studies (T47)

2. Design and Construction Documents (T47,48)

3. Training and Start-up Assistance (T50,51)

Results

The plant was installed in a building located within a compound of the National Milling Corporation. National Milling was producing corn grits and other cereal products using milling equipment located at this facility. The LEC plant had capabilities to receive and store processed corn grits, to receive, clean and decorticate whole soybeans before storage, extrude, mill and blend minor ingredients with the extrusion cooked product.

To assure that the installation was made in a timely manner, several trips were made to Tanzania to coordinate with personnel (T48,49,50) and to provide technical inputs during installation and start-up (T51).
Capital costs for the plant, as installed, are summarized below.

Engineering and Technical Services	$ 38,400
Installation and Start-up	*
Processing Equipment	49,884
Total Cost Less Working Capital	$ 88,284

*Not Reported

Colorado State's input to the project design and plant operation were made over the project life of approximately four years. Levels of input into this project during the four years of activity are given below by input type.

1. In-Country Assistance 20 man-weeks

2. In United States 62 man-weeks

3. Consultants 4 man-weeks

The plant began operation producing a corn/soybean mixture which was fortified with milk powder, vitamins and minerals which was distributed to the public sector and the commercial market. The plant operated successfully for approximately two years at acceptable processing efficiencies. After the two-year period of operation, the plant began to experience a number of problems with product quality. Specifically, attempts to commercially sell Lisha in local markets failed because infestation occurred in the bags on the shelves. The actual causes for this contamination could not be determined; consequently, speculation of causes and faults resulted in a poor project environment. Secondly, austerity lead to severe foreign exchange shortages for the purchase of parts and upgraded packaging equipment. The withdrawal of the USAID mission coupled with the above problems contributed to the plant terminating operations. Information on other causes were published by Easterbrook in Science 85.(MR9)

2.5.0 Technology Transfer

Colorado State University has made extensive efforts to transfer the LEC technology worldwide with efforts:

1. To provide a data base containing information about the technology for interested parties.
2. To make available current and updated publications on the LEC technology.

3. To provide a facility for testing and product development by parties interested in the technology.

4. To develop methods of promoting LEC and extrusion for making nutritious foods for different aged children and adults.

5. To continue development of the technology.

Several mechanisms were used to transfer the technology, including:

1. International workshops (R1,7)
2. Newsletters (NL1-26)
3. A Technology Transfer Center (R15)
4. Modular plant design (S9)
5. Providing proforma capital and operating cost estimates (S19,20)
6. Operations training manuals (S8)
7. Seminars
8. Training courses

Extensive publications, demonstrations, correspondence and other vehicles disseminated information to interested parties and has been effective in promoting and transferring the LEC technology. The following sections discusses these efforts used to achieve technology transfer goals.

2.5.1 International Workshops

Two workshops were sponsored and organized by the project. They assembled a body of people from different areas of the world to discuss and report their interest and work on LEC technology. The first workshop was held June 2-5, 1976, at Fort Collins, Colorado, and had approximately fifty people participating.(R1) The purpose of this workshop was to introduce the technology to a group of food scientists and project administrators and

to determine how best the needs of potential users might be served. One result of this workshop was the establishment of Colorado State University as the clearing house for information on the LEC technology. Another important result was the establishment of a newsletter to keep people informed of developments in and exchange information about the technology. Participants established priorities for future work on LEC in the areas of: 1) product evaluation--nutritional and physical properties, 2) improvements in manufacturing operations, and 3) program assistance.

A second international workshop was held January 15-18, 1979, in Dar es Salaam, Tanzania, hosted by the National Milling Corporation and Colorado State University.(R7) Forty-three participants related their first-hand experience with the LEC systems in developing country settings. The extent of the utilization and experience with LEC was a striking contrast to the first workshop where the focus had been on the potential for LEC applications. Following presentations by the participants, working groups identified a number of future LEC activities. These were categorized in the areas of: 1) process improvements, 2) product developments, and 3) marketing of LEC food products.

The workshops served a vital role in the evaluation, information dissemination and transfer of the technology. The project's ongoing activities were directed by inputs given by the potential user community. The complete proceedings of these workshops were published as LEC reports numbers 1 and 7.(R1,7)

2.5.2 Newsletter

The LEC Newsletter has been the most cost and technically effective tool to provide information to interested groups and followers of the project. The first edition of the Newsletter was published January 1977 and concluded with the issue published in July 1989. The LEC Newsletter was published twice each year and contained updated practices and new uses of LEC throughout the world.(NL1-26) (See Appendix B)

The Newsletter, within the last two years, polled its readership to determine how best the publication could continue to serve this specialized group. The majority of the responses indicated that the Newsletter should feature interviews with key individuals involved in the technology, provide a wider focus on extrusion through literature reviews and to publish more technical information. The last three issues of the Newsletter attempted to incorporate these recommendations.

As of the last issue of the LEC Newsletter, a readership of approximately 750 people were receiving the publication. A number of inquiries were made to specific articles as a result of information published for each issue. To maintain interest in the project, a mechanism should be found to continue publishing the LEC Newsletter.

2.5.3 Technology Transfer Center

Over the duration of the LEC project, considerable experience and expertise has been developed with LEC applications. These experiences clearly point to the fact that successful project development requires the strong interest of an individual, organization or governmental agency in the developing country who would serve as a focus for the technology

transfer. Once a potential project has been identified, work is required to establish project feasibility, management, raw material availability, product acceptability, product specification, financing, plant design and construction, plant operation, ongoing technical assistance, etc.

Some of the expertise to perform these necessary functions exists in the developing country. Successful transfer of technology requires that developing country expertise have access to information and assistance to supply any missing ingredients to assure a successful project. To fill this need, a Technology Transfer Center (TTC) for LEC application was proposed and funding possibilities were explored.

Numerous alternatives were considered for the organization and operation of a Technology Transfer Center. Attempts to find the funding necessary to establish the center were made. Unfortunately, most potential funding sources did not have the necessary resources or organizational mandate to provide the monetary backing for the center. The World Bank and UNIDO also expressed the position that a TTC should be based overseas and not in the U.S. Most groups approached with this idea indicated they would be in a position to use the center if it existed.

Despite the difficulties in funding a transfer center specifically for LEC technology, Colorado State University continued to assist in evaluating and applying the LEC technology to the production of nutritious foods in developing countries using resources provided by cooperative agreements with the USDA/OICD. Technical services provided under this agreement included feasibility studies, nutritional consultation and evaluation, comparison of alternative processing systems, product developments and evaluation, plant and process design, equipment specification and/or

purchase, installation, training, start-up and backstopping. In some cases, this work was preformed in conjunction with marketing specialists from Texas A & M University, short term consultants, and other individuals.

2.5.4 Modular Plant Design

To reduce the up-front costs to design a plant, specify equipment, and construction, Colorado State University developed a modular plant design.(S9) The purpose of the modular approach was to facilitate the application of the LEC technology into existing systems by making it easily adaptable to a variety of circumstances, to increase the flexibility of a processing system to manufacture a range of products which would be suitable and acceptable in developing countries, and to incorporate the best features of past LEC plant designs as determined by experience.

The modular plant design included the layout of equipment, equipment specifications, a general description of module operations and proforma plant economics. Four basic modules were designed including: 1) grain cleaning and dehulling, 2)processing, 3) blending, and 4) packaging. This design combined with LEC products, application and operations experience has enabled Colorado State University to provide technical assistance to interested parties throughout the world. To date, the modular plant design concept has been partially utilized at two locations, Guyana and Sri Lanka. Guyana used the modular concept to add on cleaning and decorticating capability for raw materials and Sri Lanka is planning to use the concept in adding on extra processing capacity.

2.5.5 Proforma Capital and Operating Costs

A number of requests were received by Colorado State University about cost estimates for processing plants with different capacities and capabilities. In order to fill these requests, two proforma capital and operating cost estimate documents were developed; one for a plant capable of manufacturing 0.5 MT/hr and one for 3 MT/hr.(S19,20) Each document contained the following information.

1. Introduction of the LEC concept.
2. Plant specifications outlining plant capabilities and limitations, production costs and estimated yearly production limits.
3. Plant layout and flow diagrams.
4. Estimated capital cost budgets.
5. Specifications and associated budgets for processing modules.
6. Optional equipment to upgrade, increase production or automate the process.
7. Proforma production cost estimation for a packaged fortified blended food product.

These documents have served a number of groups in evaluating the LEC technology and to correctly budget for equipment and services associated with commissioning a new plant. The major problems in using these documents has been in keeping them updated and tailoring them to meet specific requirements of requests. To meet special needs, each document has an option section where specific processes modifications and their associated costs are listed.

2.5.6 Operations and Training Manuals

The project discovered that a number of LEC sites and interested parties lacked equipment manuals and information that addressed operating principals of plant equipment. In addition, a number of plants were without specific information about managing a plant and assuring product quality. In response to these groups and to improve the operations of existing and new LEC plants, a set of operations manuals were developed which could be provided to plant sites and other groups who wished to know more about specific equipment and plant operations.(S8) The manuals were written into two separate documents; Part I dealing with the day to day operations, administration and quality control of plant production and Part II addressing the various types of equipment used in an LEC plant. The document was useful especially in cases where manufacturers of equipment provide little or no operational information with their machines.

2.5.7 Seminars

Papers and presentations were given throughout the project addressing the implementation and use of LEC technology. Specifically, presentations were given at conferences at Chihuahua, Mexico, the Association of South East Asian Nations (ASEAN), American Association of Cereal Chemists, Chile, Venezuela, INCAP-Guatemala, Massachusetts Institute of Technology, Meals for Millions, International Soybean Short Courses, etc.(PB1,2,3,4,5,12; P1; R17; PR1,2,3)

The presentations given and discussed have been a most effective tool in establishing working relationships and stimulating interest in the LEC technology. One-on-one interaction has led to a greater understanding of

needs of interested parties by the project personnel and a clearer understanding of the technology by those interested.

2.5.8 Training Courses

Recently, an extrusion short course has been made available to interested individuals to assist them in learning about the theoretical and applied aspects of extrusion, nutritional and quality assurance issues of extruded products, marketing of products and plant design/equipment selection. The short course, spanning two weeks, provides classroom experience as well as laboratory demonstrations, hands-on experience and testing. The course draws heavily upon experience gained from LEC activities since a number of the participants are from countries where LECs are most likely to be used. The short courses have been self funded and have not required any financial support from AID/ST/N or USDA/OICD.

2.6.0 Technical Assistance

Additional activities at Colorado State University included providing technical assistance to locations having plants designed and installed by local personnel utilizing extruders and/or requiring training. This section describes the efforts to provide technical assistance to various groups.

2.6.1 Guyana

Background

As a result of a Government of Guyana (GOG) survey, a recommendation was made that a low-cost weaning food, based on rice, legumes, plantain flour and soybean be manufactured in Guyana to reduce the incidences of first- and second-degree malnutrition. The recommendation was adopted in a food and nutrition policy prepared by the Ministry of Health.

A group of individuals working for the Guyana Pharmaceutical Corporation (GPC) were directed by the GOG to examine how to establish a food processing capability to meet this goal. A search to find appropriate technology eventually led GPC to visit the Costa Rican LEC demonstration plant and observe how the technology might fit into their project needs. GPC felt that the technology could play a significant role in helping to achieve a satisfactory low-cost product and requested USAID's assistance in procuring the necessary equipment and technical help to achieve their goals.

Initially, an extruder was purchased to test different products and formulations using locally available raw materials. Based on these tests, a formulation was chosen and was the basis for design of a complete processing facility to make a baby food product called "CEREX."

Project Objectives

The project was initiated with the following objectives:

1. To provide a processing facility capable of manufacturing CEREX from extruded indigenous raw materials and donated commodities.

2. To develop a distribution system capable of supporting national sales of the weaning food.

3. To determine if a food manufactured using LEC had commercial viability and be sold on a consistent basis.

Methodology of Meeting Goals

Key inputs were made to the project which helped to make the project and plant successful. Inputs of technical assistance were provided through out the eight-year project and include:

1. Feasibility Studies (T20)
2. Design and Construction Documents (T20, S17, T27)
3. Training and Start-up Assistance (T19,21,24,27)
4. Troubleshooting and Backstopping (T23,25,27)

Results

A plant was designed by Colorado State, installed and began operation in March 1980 in Georgetown, Guyana.(T20) The facility had the capability to receive precleaned and decorticated grains from imported shipments or from local suppliers. These materials were then blended and ground, extruded, cooled, milled and finish blended with other preprocessed ingredients to complete the formulation. A hand packaging operation was used to fill and seal the 500 g polyfiber bags. In 1986, cleaning, destoning and decorticating equipment was added to the front end of the process to enable the plant to make a totally indigenous CEREX product. It operated on a consistent basis for approximately five years; but from 1986 to the present, it has operated sporadically due to unavailability of raw

material and lack of spare parts. The product from the processing plant found significant acceptance in commercial markets.

To assure that installation and other activities were completed in a timely manner, several trips were made to Guyana to coordinate with personnel (T19,21,23,24,25,17) and to assist in training and start-up.(T19, 21,24,27) Data on operations of this facility could not be collected because of an unusual accounting system used by GPC. Specifically, the process plant was one of many processing units administered as one business. During attempts to obtain information on the operations, it was not possible to separate the various production cost elements for the LEC process from those of other processes or products. Therefore, cost data could not be summarized.

Levels of effort extended towards completion of this project including adding the front-end cleaning equipment are summarized below.

1. In-country Assistance — 17 man-weeks
2. In United States — 42 man-weeks
3. Consultants — 0 man-weeks

2.6.2 Mexico

The Chihuahua State Government of Mexico (CSGM) was interested in utilizing one of the major agricultural commodities (soybeans) as a nutritious supplement for traditional staple foods. The CSGM turned to the Centro de Investigaciones y Assistencia Tecnologica de Estado de Chihuahua, A. C. (CIATECH) which was headed by a group of engineers and scientists charged with using modern technologies to solve the social and economic problems of the region.

The Chihuahua program was established in a relatively short time and with only minimal outside assistance. One factory at Delicias produced full-fat soy flour which was sold as an enriching agent to private food manufacturers and to the Mexican Government chain stores for fortifying tortilla flour. A second factory was established to supply soybean fortified corn flour to Indian children in the Tarahumara region. A third plant sold reconstituted milk fortified with extruded soy through stores serving low income groups.

Three plants were built within two and one-half years and with a total investment of only $700,000. The plants have run on a continuous basis and were maintained through local manufacture of spare parts and much of the equipment. The success of these efforts eventually led to a line of extrusion equipment built by CIATECH which qualify as LEC-type equipment.

To gain further understanding of the LEC process when CIATECH first became interested, CIATECH personnel came to Colorado State University. During the trip to Colorado, the group learned about the technology, how to run the extruders, and obtained specific ideas on how to design a full-fat soybean flour plant using LEC. Additional assistance has been provided on-site to help promote the technology CIATECH has developed by participating in workshops and to solve specific processing problems in-country.(T30)

The amount of effort extended towards the project in Chihuahua, Mexico, is given below.

1.	In-Country	3 man-weeks
2.	In United States	6 man-weeks
3.	Consultants	0 man-weeks

2.6.3 Thailand

Kasetsart University in Bangkok, Thailand, had an ongoing effort to develop food products suitable for use in intervention feeding programs to help reduce the incidence of malnutrition in their populace. The majority of their development work was done using Wenger-type extrusion equipment until they became aware of LEC. The University made arrangements to obtain a Brady extruder which they could use to develop foods similar to those produced on the Wenger. This effort was directed towards minimizing the capital investment required for processing plants in Thailand since multiple units were envisioned. Colorado State University provided assistance to help Kasetsart personnel learn how to operate the LEC.(T52)

The King's Project in Northern Thailand had requested Kasetsart University to design a plant that could make a nutritious low-cost food product to distribute to people in Northern Thailand mountain tribes. In response to this request, Kasetsart designed and installed anLEC system in Chiang Rei. The unit was installed and started up, but a number of problems occurred.

To help solve problems in the plant, on-site assistance was provided to the project by Colorado State University.(T53) Problems addressed during the assistance period included retraining operators in running the Brady extruder and solving cooler and milling problems. Upon completion of the assistance period, the plant was operational and could produce the rice/soybean-based food "Doikan."

The level of effort required for the assistance and follow-up is given below.

1. In-Country 2 man-weeks

2. In United States 2 man-weeks

3. Consultants 0 man-weeks

2.6.4 Zaire

Victoria Associated Products (VAP) of Kinshasha, Zaire, was manufacturing a product called CEREVAP which was a corn/wheat-based baby food. VAP approached USAID to establish funding and obtain assistance in selecting a process to make a satisfactory baby food in greater quantities. To select a process, VAP personnel traveled to the United States to review various processes including extrusion processing. Four extruders, Wenger, Brady, Insta-Pro and Anderson, were selected as candidates for making the food.

Colorado State University assisted VAP while in the United States by obtaining raw materials similar to those used to make CEREVAP, milling and blending the ingredients, and shipping them off to the various sites where the extruders would be tested. The Brady and Insta-Pro extruders were tested at Colorado State University, the Wenger at the pilot plant of Wenger, and the Anderson at Texas A & M.

After visiting the above facilities and testing the extruders, a decision was made to buy an Anderson extruder and ancillary equipment to support the machine. Anderson International was asked to provide a plant design and equipment specifications to make the CEREVAP product. Upon completion of the design, Colorado State University reviewed the design and passed comments onto VAP and Anderson. Several iterations of this activity were completed before a final design was approved.

The plant, as installed, had the capacity and capability to process raw materials into the CEREVAP product. Two 4.5" Anderson extruders were installed which gave sufficient capacity to meet the processing demands for CEREVAP and to develop additional products to sell in Zaire and other African nations.

The amount of effort expended to assist VAP on this project is listed below.

1. In-Country 0 man-weeks
2. In United States 5 man-weeks
3. Consultants 0 man-weeks

2.6.5 Bolivia

LEC was first introduced into Bolivia through a private company, Nutrinal. Nutrinal was primarily interested in processing animal feed but saw potential in processing human food products for the Government of Bolivia (GOB). The Government was requesting a processed food product made from corn and soybean that could be used for weaning-food supplements. Assistance from USAID was required to help design a facility to provide the food to the GOB and assist in setting up plant operations.

Colorado State University provided the above assistance and also helped review plans for production and marketing of the product.(T4) Assistance was also provided during plant start-up and operation, to develop a quality control program and to advise on vitamin and mineral addition.(T5) A corn/soybean product called "Maisoy" for the GOB and small amounts of ready-to-eat breakfast cereal have been manufactured by the company.

The level of effort required to assist the project in Bolivia is given below.

1.	In-Country	2 man-weeks
2.	In United States	1 man-week
3.	Consultants	0 man-weeks

2.7.0 Feasibility Studies and Project Designs

The undertaking of the installation and operation of a central processing facility for the production of nutritious weaning foods represents a significant investment. The ultimate success of the project depends on the availability of raw materials, capital for the installation of the plant and its initial operation, capable and interested management, acceptance of the product and the existence of a market for the plant output. Requests for feasibility analysis of using LEC processing plants were received as the result of the technology transfer activities developed under the Cooperative Agreement. Using the experience and expertise developed in the demonstration portion of the project, multidisciplinary teams consisting of food technologists, engineers, nutritionists and marketing specialists undertook these studies and/or project designs. Comprehensive studies and/or designs were done in Ecuador, Egypt, India and the Sudan. Some of these studies became the bases for project papers.

2.7.1 Ecuador

The Ministry of Health (MOH) of the Government of Ecuador (GOE) initiated the distribution of a food supplement to the nutritionally vulnerable starting in 1974. The supplement was a product called Leche

Avena which was made from rolled oats, defatted soy flour, and non-fat dry milk.

Target beneficiaries for the product were pregnant and lactating women, at risk children under two and malnourished children under six. Raw materials came from several sources including Food for Peace, European Economic Commission and World Food Program. Because of the interest and high visibility of the program, the MOH planned to expand the number of beneficiaries and to produce a product principally made from local food inputs rather than rely on donated inputs.

Coincident with the development of the project in Ecuador, the ANDEAN Pact had been interested in the development of appropriate processes to locally manufacture nutritious foods from indigenous raw ingredients. Working cooperatively with the MOH, they purchased equipment for a low-cost extrusion cooking line to produce 400 MT/yr.

Since the LEC technology was relatively new to these groups, they requested assistance from the USAID Mission to help define the project objectives and review the plans for the plant and project.

In January 1982, J. M. Harper, G. R. Jansen and R. Bressani evaluated an LEC processing plant design and project to replace Leche Avena (a mixture of cooked oats and NFDM).(F2) The plant was being constructed by the Ministry of Health in Ecuador and in its formative stages of development. The team studied and made specific recommendations on the following subjects:

1. The design, installation and operation, including processing costs, for the LEC plant.
2. Production and raw material requirements to meet product demand.

3. A comparison of the nutritional characteristics of the processed food with the needs of the consuming children.

4. The potential for Leche Arroz (cooked broken rice and NFDM) to meet the needs of the target population and serve as a substitute for Leche Avena.

5. Vitamin and mineral supplementation requirements for the foods.

6. Quality control procedures and standards for the product.

7. Evaluation of the centrally processed weaning food factory.

As part of the project, two Ecuadorian engineers were sent to Colorado State University for training and to learn more about the technology. Colorado State University also provided on-site assistance to help finish the installation of the plant, shake down the equipment, train, and start-up the plant for production.(T17)

The installation and start-up of the plant was in 1982. During start-up, several problems were identified and subsequently resolved so that production was possible. The plant has operated only sporadically since the start-up due to many unrelated causes. There is currently some ongoing activity to reactivate the plant and develop a new product suitable for commercial sales.

The level of effort extended towards the project is given below.

1.	In-Country	4 man-weeks
2.	In United States	4 man-weeks
3.	Consultants	3 man-weeks

2.7.2 Egypt

Surveys documented that malnutrition was widespread and a serious problem among infants and children in Egypt. Inexpensive food supplements and improved weaning practices were felt to offer some relief for this problem. A high protein and energy-rich supplement fortified with vitamins and minerals could be added to cereal ingredients found in the home to produce a nutritionally rich weaning food at very low cost. A study was undertaken to determine the feasibility of developing a low cost, culturally acceptable weaning food supplement, adapting the public health clinics as effective distributors of the supplement, and distributing the supplement through the private sector. This study laid out the general parameters for a proposed USAID project which involved extensive development and market testing of a supplement consisting of extruded full-fat soy fortified with vitamins and minerals. In parallel with these product developments, work would be undertaken to formulate and test operational strategies to increase the effectiveness of the public health clinics' demonstration and distribution of the product. Market testing in the private sector was proposed and designed.

Based on positive results from the development and testing proposed in the project, a follow-on project was outlined which would provide production facilities, health center training and initiate the manufacture and distribution of the weaning food supplement on a national basis. Details of the project proposal are contained in separate reports.(F3,4,5) Funding for the development of the product and its testing was not authorized; however, the project was never implemented.

Level of effort required for this study is listed below.

1.	In-Country	4 man-weeks
2.	In United States	2 man-weeks
3.	Consultants	3 man-weeks

2.7.3 India

The Ministry of Social Welfare and Women of the Government of India and USAID developed an Integrated Child Development and Survival (ICDS) project to produce and distribute ready-to-eat supplementary foods for malnourished children. The plan called for the installation of pilot central processing plants in Gujarat and Maharashtra States to demonstrate the concept. The project was called upon to perform a feasibility study to evaluate LEC and roasting processes for the manufacture of supplementary food products and to make recommendations on the composition and nutritional characteristics of the products which were to be produced. J. M. Harper and G. R. Jansen went to India in August 1985 to perform the study funded by John Snow Associates with support from USAID/New Delhi.(F6)

Data were gathered by examining existing roasting and LEC plants in India in order to understand manufacturing procedures, costs and the types of products being produced. Manufacturers of equipment were also contacted to determine the cost and capabilities of indigenous equipment suitable for the manufacture of human food products. Based on an analysis of the alternative roasting/grinding and LEC systems, both were found to be capable of producing a nutritious and hygienic supplementary food in the India setting. Costs for the production of a roasted product were slightly lower than for the extruded product, but the roasted product had little solubility in water and could not be used as the basis for an instant

gruel, as was the case for the LEC product. The roasted product could be formed into a doughy ball by the addition of a small amount of water and consumed by weaning-aged children.

Since no data existed on the acceptability of the alternative food types, it was recommended that both a roasting and LEC plant be installed as part of the pilot project. Plans for the pilot plants were reviewed and suggestions given for process modifications and improvements to improve their ability to consistently manufacture low-cost foods.

2.7.4 Sudan

The Food Research Centre (FRC), Khartoum, Sudan, had an ongoing effort to investigate expanded usages for locally grown foods, such as sorghum and millet. One of the traditional uses for these grains was a preparation used as a weaning food called Nasha.(MR8) This product was made from either of these grains by first fermenting the grain followed by a slow cook. Because this product was time consuming to prepare and had limited nutritional value, FRC sought ways to produce an easy-to-prepare product of improved nutritional quality that retained the flavor and acceptability of traditional Nasha.

USAID/Khartoum, in cooperation with the USDA, agreed to assist FRC in studies and development of lower-cost methods of producing an instant-type Nasha product. A test program was initiated at Colorado State University to explore possible formulations and processing techniques. Formulations were developed using sorghum, fermented sorghum, soybean oil and peanuts which are all available in Sudan. These formulations were extruded on the Anderson extruder. Laboratory testing followed to determine the quality of

the products. Additional tests were run on the digestibility of the mixtures. Colorado State University was unable to formulate a product with a strong traditional fermented flavor, but a non-fermented product formulated from peanut and sorghum was judged by Sudanese workers to be a satisfactory substitute. Specifics of the test program have been outlined in a separate report.(S14)

Samples of the non-fermented product were shipped to the Sudan for acceptability studies; the results of which were positive. Based on these results, a study was undertaken in Sudan to assist in determining the feasibility of private sector manufacture of the extruded weaning food for the commercial market.(F7) To ascertain the feasibility, the team specifically examined the investment requirements, cost of production, nutritional characteristics of the food, product acceptability, a commercial marketing strategy, sales potential, general business climate, and capabilities and interest in the private sector.

Although the present economic conditions in Sudan presented many difficulties for the private sector, the initiation of a commercial project to produce and market weaning food appeared possible. Problems with foreign exchange, price controls and government guarantees for product purchases were seen as obstacles to overcome for a successful project. There was a potential market for a centrally processed weaning food if a concerted marketing program were undertaken. The size of the market was estimated to be 1,000-1,500 MT/yr or higher.

Based on the original plan for the project, arrangements were to be made for importation of Sudanese raw materials into the United States for processing at Colorado State University. Unfortunately, a number of

obstacles were experienced with the United States APHIS Office. The sorghum from Sudan was seen as a potential carrier of air-born contaminants and would require special treatment. Colorado State University could not comply with APHIS requirements and informed the USAID mission of the problems. A cable from Sudan indicated that a decision not to proceed with the project had been made and no further work would be done due to the economic conditions in the Sudan.

2.8.0 Rice Bran

One of the major problems in most developing countries is a shortage of vegetable oils. Vegetable oils add caloric value and acceptability to diets, but they are often quite expensive. The high cost of the quality vegetable oils results from insufficient local sources and thus a need to import.

Many developing countries, while oil deficient, have a source of high quality oil available from rice bran. Separating the oil from the bran in an expedient method has been a major deterrent for considering this oil. The oil needs to be extracted from the bran in a relatively short period of time to maintain high recovery efficiencies. If the oil remains in the milled bran for periods longer than 12-24 hours, natural occurring hydrolytic lipase enzymes break the oil into free-fatty acids (FFA) which causes low oil recovery and refining to be uneconomical.(MR1,2)

Heat treatment of the rice bran was shown to be effective in inactivating the enzymes.(MR2) Most heat treatments for the bran involve some type of steaming step followed by pelleting. Pelleting was required

to minimize the amount of fines in the bran which plugged the bed, filters and other equipment in the solvent extraction system.

LEC were envisioned as having potential to stabilize rice bran and possibly agglomerate the product. The Western Regional Research Center (WRRC), USDA/ARS, Albany, California, obtained an LEC and began testing the unit for effectiveness in stabilizing rice bran. Colorado State University cooperated with WRRC during the initial phases of the test program, assisted in specific problems with the extruder, and helped to perform a matrix of test conditions using LEC to determine the optimal extruder conditions for bran stabilization.(T3, MR2) WRRC, after further testing, determined that the LEC could be used to stabilize rice bran but were unable to determine if the bran could be extracted in a commercial solvent extraction system.

A survey was conducted by Colorado State University to gather preliminary information on the extractability of extrusion stabilized bran. Individuals and groups worldwide having expertise in extracting oils from oil bearing materials, manufacturers of solvent extraction equipment, consultants, etc., were sent samples of extruded bran and a survey questionnaire. The survey results indicated that the bran could be solvent extracted in commercial units of the rotacel type or that were configured with nonagitated beds or baskets. Continuous belt-type extractors appeared less promising in relation to their ability to extract the bran because of fines.(S6)

A simplified test on extractability of rice bran was performed at Colorado State University.(S7) This test gave supporting data that the extruder stabilized bran was extractable having a higher percolation,

drainage and extraction rate than that of commercially prepared soybean flakes. Tests were also done at Colorado State University to define and establish guidelines on standards for rice oil (S10) and evaluation of storage conditions suitable for rice bran.(S11)

A meeting, held in 1983 at Colorado State University, involving all of the principals working with the rice bran stabilization project led to a decision to start a project to stabilize, extract, refine and market rice bran oil and rice bran products in the Philippines. The Philippines was selected due to previous involvement with rice bran oil manufacture and an interest in demonstrating extrusion stabilization.

The project was set up with the following objectives:

1. To determine if rice bran could be stabilized in a commercial operation.
2. To determine if LEC could stabilize bran continuously and consistently.
3. To determine the parameters necessary to extract and refine oil from stabilized rice bran.
4. To determine the marketability of rice oil and extracted rice bran products in a developing country.
5. To determine the economic feasibility of stabilizing and extracting rice bran.
6. To determine the infrastructure required to collect, transport and stabilize rice bran coming from several mills.

Key inputs were made to the project to help facilitate the demonstration. Inputs of technical assistance were provided throughout Colorado State's four-year involvement with the project and include:

1. Feasibility Studies (T32)

2. Design and Construction Documents (T33,34)

3. Training and Start-up Assistance (T35)

4. Troubleshooting and Backstopping (T36)

A processing plant consisting of conveying equipment, bran storage, extruder, holding conveyor, cooler and manual bagger was installed in a large warehouse and milling compound operated by National Food Authority (NFA) in Cabanatuan City, Philippines. The plant was designed to operate in conjunction with a Satake Rice Mill located in the same building. NFA mills were operated only when rice was needed to stabilize the market price. Therefore, provision was made to collect bran from nearby private mills so that the stabilizer plant could operate continuously. The plant operated sporadically for approximately one year, during which several problems arose including:

1. Excessive extruder wear--High wear was attributed to bran quality and the offset drive system for the extruder.

2. Poor extruded bran stability--Stabilized bran stored in a warehouse experienced increasing levels of FFA during storage. The real cause was not determined but suspected to be inappropriate processing or external contamination of the stored bran with rice bran dust or insects.

A typhoon stopped the power supply to the plant and repairs took approximately three months. This was followed by a change in Government leadership which ultimately led to a change in NFA administration. Because of these circumstances and the inability to return to the site to work, the

above problems could not be solved and a number of questions could not be answered including:

1. The feasibility of collecting and stabilizing bran purchased from private millers.
2. The extractability and refining of the bran and oil.

These changes led to the project being terminated in 1988.

A draft summary report of information dealing with the findings and problems in stabilizing rice bran was prepared.(MR3)

Effort required for the tasks outlined is given below.

1.	In-Country	15 man-weeks
2.	In United States	18 man-weeks
3.	Consultants	10 man-weeks

2.9.0 Other Extrusion Projects

Several additional and/or specialized projects were undertaken under the contract to further the technology and/or to define new uses for the extrusion technology. These projects include:

1. Oral Rehydration Therapy
2. Catch-up Food
3. Texturization of Full-fat Soybean
4. Roasting

2.9.1 Oral Rehydration Therapy

Many children between 0-2 years of age will have at least one moderate to severe case of diarrhea. Diarrhea is a cause of dehydration and minimizes the benefits from ingested foods since they do not stay in the

digestive track long enough for absorption of essential nutrients. One appropriate way to assist children recovering from diarrhea is by administering a liquid solution made from glucose and water which is enriched with electrolytes and nutrients. Children given this solution recover more rapidly from the illness with less growth faltering.

Researchers (MR4) have also determined that if the oral rehydration solution (ORS) is made from a cereal base rather than sugar, retention of the solution in the gut is much longer giving additional time for nutrient absorption. The primary problems associated with ORS made from cereals has been optimizing functional performance of the starch in the cereal to increase caloric intake by the child.

A study was undertaken at Colorado State University to examine how to extrude a cereal product to optimize its functional performance and caloric level of ORS. Specific objectives included:

1. To determine an optimum extrusion condition for rice that produces the desired functional characteristics for ORS.
2. To characterize extruded samples and compare results with different extrusion conditions.
3. To compare functional characteristics of the extruded samples with a control.
4. To recommend a product for evaluation in the Bangladesh ORT program.

It was found that extrusion cooked cereal can improve ORS over those prepared from raw rice flour, making the prepared solution more calorie dense, easier to prepare and have improved flavor. It was possible to add up to 25% more extruded cereal to a quantity of water compared to raw rice

flour which netted a caloric content increase. The added amount was not as high as one might obtain using other processed materials, such as parboiled rice flour, maltodextrins, etc., and the final choice of processing would depend on cost and capability of the formulation to achieve the desired results. It was recommended that clinical testing be done to determine the effectiveness of the products made with the extruder.(S13)

2.9.2 Catch-up Food

A related issue to the ORT mentioned in the previous section is specialized foods that rehabilitate malnourished children suffering from diarrheal disease and provide an added supply of high quality nutrients, vitamins and minerals. The primary purpose of this food is to recover a child from either a diarrhetic or other intestinal illness as quickly as possible. Research has determined that when children reduce food intake for several days because of an intestinal illness, the result is a rapid decline in their normal growth pattern. If the illness goes for extended periods, stunting is often the end result.

A special food that has high quality protein, is calorie dense and contains essential electrolytes and other nutrients, is desirable for children recovering from diarrheal disease to help them regain their status on the growth curve. Because of the food's special requirements and use, it must be specially formulated and processed so that it could be conveniently used by mothers.

The problem has been in formulating a food that would provide the necessary requirements outlined above. Issues such as lactose intolerance, allergies, etc., needed to be addressed. Colorado State University was

interested in this problem and began a preliminary search for materials and formulations that might fit into the category of catch-up foods. The work on the product development was stopped in 1989 and no further developments have been made.

2.9.3 Texturization of Full-fat Soybean

The procedures and techniques to texturize defatted soybean meal have been well established. These techniques have not been defined for full-fat soybeans or other oil bearing materials when the oil is present.

The LEC project learned of an effort to texturize full-fat soybean in California. A trip was made to the facility to examine the techniques and processing used to make the product. During the visit, it was discovered that texturized product had only been made on a limited basis and that the technique was not fully developed. Furthermore, texturization had only been done in a laboratory-sized extruder and had not been done on a pilot or commercial scale. The group developing this process was not interested in testing and developing the concept in more detail.

Therefore, Colorado State University began a test program to determine how to make a textured full-fat product. Specific objectives of this study included:

1. To test and develop a textured soy product which can be made directly from whole soybean using LEC equipment (Anderson).
2. To define the processing parameters necessary to make the textured product continuously, including:
    A. Raw material pretreatments such as grinding, dehulling, pH adjustments, moisture.

B. Equipment configurations including the die and screw, screw speed, cooling and heating of the extruder components.

The study was conducted to determine the critical process parameters in making FFTP. The study began with existing equipment attempting to replicate the conditions used by Allred and Sterner, which were:

1. Ground whole soybean containing 10% added water and 1% sulfuric acid.
2. Extrusion temperature of 317°F at the die.
3. Special double die plate.
4. L/D of screw 20:1.

Modifications were made as needed, placing priority on those which required minimal alteration to the Anderson machine, such as changing the number of breaker bolts and their depths along the length of the screw, altering the screw design, or die design changes.

The initial study utilized a matrix of parameters as follows:

1. Moisture of Ingredients--3 levels (16, 18, 22%).
2. pH--3 levels (6, 7, 8).
3. Temperature--3 levels (300, 320, 340°F).
4. Screw Speed--1 level--400 rpm.
5. Screw Configuration--2 levels (standard, added steam locks).
6. Die--2 levels (single die, double die).
7. Extruder--1 level (Anderson).

Tests run used a number of different moisture conditions and temperatures. Surging was quite common during most of the testing caused from an inability to feed the extruder consistently and a difficulty in conveying products effectively because of slippage at the barrel wall

surface of the extruder. In addition, a consistent texturization could not be achieved due to the surging, however, product exiting the extruder during the surge cycle showed evidence of texture. This product was examined and determined to be higher in both moisture and temperature than the product which could be made consistently without surging. This observation led to the conclusion that in order to texturize the soybean adequately, more moisture and a higher heat addition was required.

Due to the timing of the project, studies could not be completed prior to writing this report. Colorado State University plans to continue testing and development of the product and processing conditions in hopes of achieving texturization. A separate report will be prepared and submitted for publication in an appropriate journal should the results look promising.

2.9.4 Roasting

Roasting was seen as a suitable alternative to cook a number of finished products and became especially interesting to the project as a process to cook full-fat soybean (FFS) for making full-fat soybean flour (FFSF). Attempts were made to make FFSF using extrusion cooked beans; however, the resulting extrudate contained a large amount of free oil which created a number of handling and milling problems. It had been observed that milling of raw soybean to fine flour had not been a problem, but that milling after extrusion was not possible due to free surface oils. Thus, a method of cooking the soybeans without disturbing the structure of the bean would be beneficial. Roasting was seen as a process that could provide this kind of treatment.

Colorado State University evaluated a series of roasters that used hot agitated salt beds to cook the soybeans.(R4,6,10) A factorial experiment of roasting process conditions that produced products which could be evaluated for degree of cook as well as nutritional and functional characteristics was designed. Results from this study showed that it was possible to produce FFSF with a high protein quality using a dry heat process and beans with initial moisture levels of approximately 5-10%. It was also found that milling the beans into a flour was much easier after roasting. The roasting process also simplified the dehulling process since roasting partially cracked the hulls which, after light rolling, were easily winnowed away in a stream of air.

Level of effort required to test the roaster was approximately 24 man-weeks.

2.10.0 Other Projects

A few projects unrelated to LEC were undertaken as a means of expanding the technology base for the project and to support other activities directed toward improving the nutritional status of people in developing countries. These efforts include:

1. Project SUSTAIN
2. Vitamin A coating of Salt

2.10.1 Project SUSTAIN

The services of Dr. Irwin Hornstein were provided to USDA by Colorado State University to develop Project SUSTAIN. Project SUSTAIN promoted cooperation between United States industry and private industry in the

developing countries. This interaction has developed a number of contacts that are interested in LEC technology which were handled by the project as received. The majority of the effort required by Colorado State University staff for this task was arranging to have a brochure on SUSTAIN assembled and printed.

2.10.2 Vitamin A Fortification of Salt

A vitamin A deficiency was identified in a number of people in the country of Malawi. The seriousness of the problem was enough to merit a study on how the vitamin might be introduced into the diets of these people. One of the potential carriers for the vitamin was thought to be salt since 90% of the people in Malawi consumed salt. Thus, a study was undertaken at Colorado State University to explore how salt could be fortified with vitamin A.(S5) Specific objectives were:

1. To determine if vitamin A complexes can be applied to salt granules.
2. To determine if long term storage loss of vitamin A occurs.
3. To determine the methodology for application of vitamin A to salt granules, including identification of equipment and materials.

Vitamin A was applied to representative salt samples obtained in the United States and Malawi. The treated samples were sent to McKesson Laboratories for vitamin A assay. Results from the tests indicated that rapid deterioration of the vitamin occurred in storage. It was thought that an incorrect emulsion system, destruction of the vitamin A encapsulation during the application or the presence of specific minerals in the salt, may have contributed to the rapid loss. Another possible

cause may have been the presence of moisture since vitamin A has been successfully added to dry salt in other efforts. While the equipment used and the methodology to apply the vitamin seemed satisfactory, more tests would be required to confirm these results. The primary conclusion reached in this study was that the application of vitamin A to salt was not feasible.

3.0.0 SUMMARY OF EXPENDITURES

The LEC project has been active starting October 1, 1974, to the present. During the course of the project, new agreements were established when needed to accommodate shifts in project emphasis and direction. The cooperative agreements during the course of the project and their costs are given in this section.

3.1.0 Contract No. 12-17-07- 5-1132 (CSU Project No. 31-1370-2114)

USDA, Economic Research Service

Title: Evaluation of Simple Cooker Extruders to Produce Human Foods for LDC's

Period: October 1, 1974, through December 31, 1975

Total Project Cost: $93,990

Total Expenditures:

	USDA	CSU
Personnel	$ 8,330	$ -0-
Materials & Supplies	14,118	-0-
Equipment	46,167	-0-

Subcontracts	-0-	-0-
Travel	1,638	-0-
Other Direct Costs*	18,406	-0-
TOTAL DIRECT COSTS	$88,659	-0-
Indirect Costs	5,331	-0-
TOTAL PROJECT COSTS	$93,990	$ -0-

*Includes consultants

3.2.0 Agreement No. 12-17-04-8-1265-X (CSU Project No. 31-1370-2139)
USDA, Economic Research Service, National Economic Analysis Division, Nutrition and Agribusiness Group

Title: Food Supplies for Feeding Programs in Developing Countries

Period: June 1, 1975, through September 30, 1976

Total Project Cost: $301,301

Total Expenditures:

	USDA	CSU
Personnel Costs	$ 94,775	$ 7,400
Materials & Supplies	22,591	-0-
Equipment	55,038	5,139
Subcontracts	-0-	-0-
Travel	58,793	-0-
Other Direct Costs*	55,241	-0-
TOTAL DIRECT COSTS	$286,438	$12,539
Indirect Costs	14,863	50,529
TOTAL PROJECT COSTS	$301,301	$63,068

*Includes consultants

3.3.0 Agreement No. 12-17-07-8-1728-X (CSU Project Nos. 1430 & 2106) USDA, Economic Research Service, National Economic Analysis Division, Nutrition and Agribusiness Group

Title: Low Cost Nutritious Foods for Less Developed Countries

Period: October 1, 1976, through March 31, 1981

Total Project Cost: $1,078,991

Total Expenditures:

	USDA	CSU
Personnel Costs	$ 120,283	$21,000
Materials & Supplies	76,666	-0-
Equipment	111,473	5,000
Subcontracts	14,581	-0-
Travel	141,475	-0-
Other Direct Costs*	540,196	-0-
TOTAL DIRECT COSTS	1,004,674	$26,000
Indirect Costs	74,317	12,760
TOTAL PROJECT COSTS	$1,078,991	$38,760

*Includes consultants

3.4.0 Agreement No. 58-319R-1-61 (CSU Project Nos. 2146 & 8374) USDA, OICD, Nutrition and Agribusiness Group

Title: Technical Assistance for Manufacturing Nutritious Low-Cost Weaning Foods

Period: October 1, 1980, through March 31, 1984

Total Project Cost: $429,062

Total Expenditures:

	USDA	CSU
Personnel Costs	$217,678	$11,183
Materials & Supplies	11,130	-0-
Equipment	-0-	-0-
Subcontracts	-0-	-0-
Travel	28,957	-0-
Other Direct Costs*	82,324	-0-
TOTAL DIRECT COSTS	$340,089	$11,183
Indirect Costs	88,973	41,493
TOTAL PROJECT COSTS	$429,062	$52,676

*Includes consultants

3.5.0 Agreement No. 58-319R-4-29 (RIC and CSU Project Nos. 6132 and 6416)

USDA, OICD, Nutrition and Agribusiness Group

Title: Technical Assistance for Manufacturing Nutritious Low-Cost Weaning Foods

Period: January 18, 1984, through March 31, 1986

Total Project Cost: $484,624

Total Expenditures:

	USDA	CSU
Personnel Costs	$ -0-	$ -0-
Materials & Supplies	7,948	-0-
Equipment	135,083	-0-

Subcontracts	257,466	-0-
Travel	15,609	-0-
Other Direct Costs*	38,770	-0-
TOTAL DIRECT COSTS	$454,876	$ -0-
Indirect Costs	29,748	-0-
TOTAL PROJECT COSTS	$484,624	$ -0-

*Includes consultants

3.6.0 Agreement No. 58-319R-6-019 (CSURF and CSU Project No. 9062)

USDA, OICD, Food Technology Branch

Title: Technical Assistance for Manufacturing Nutritious Low-Cost Weaning Foods

Period: March 31, 1986, through August 31, 1988

Total Project Cost: $320,480

Total Expenditures:

	USDA	CSU
Personnel Costs	$ -0-	$ -0-
Materials & Supplies	7,839	-0-
Equipment	5,372	-0-
Subcontracts	242,286	-0-
Travel	19,318	-0-
Other Direct Costs*	30,332	-0-
TOTAL DIRECT COSTS	$305,147	$ -0-
Indirect Costs..............	15,333	-0-
TOTAL PROJECT COSTS	$320,480	$ -0-

*Includes consultants

3.7.0 Agreement No. 58-319R-8-002 (CSU Project No. 9074)

USDA, OICD, Technical Assistance Division

Title: Technical Assistance for Manufacturing Nutritious Low-Cost Weaning Foods

Period: September 1, 1988, through September 30, 1989

Total Estimated Project Cost: $154,289

Total Estimated Expenditures:

	USDA	CSU
Personnel Costs	$ 71,333	$ 4,910
Materials & Supplies	5,000	-0-
Equipment	-0-	-0-
Subcontracts	-0-	-0-
Travel	9,700	-0-
Other Direct Costs*	44,873	-0-
TOTAL DIRECT COSTS	$130,906	$ 4,910
Indirect Costs	23,383	30,408
TOTAL PROJECT COSTS	$154,289	$35,318

*Includes consultants

SUMMARY OF ALL EXPENDITURES ON THESE AGREEMENTS:

	USDA	CSU
Personnel Costs	$ 512,399	$ 44,493
Materials & Supplies	145,292	-0-
Equipment	353,133	10,139

Subcontracts*	514,333	-0-
Travel	275,490	-0-
Other Direct Costs**	810,142	-0-
TOTAL DIRECT COSTS	$2,610,789	$ 54,632
Indirect Costs	251,948	135,190
TOTAL PROJECT COSTS	$2,862,737	$189,822

*Includes CSU personnel costs, etc., while the agreements were between (1) Research Institute of Colorado and (2) Colorado State University Research Foundation.

**Includes consultants

4.0.0 OBSERVATIONS

4.1.0 LEC Studies

The extensive work in this study directed toward determining the capabilities and limitations of LEC for producing precooked nutritious food mixtures from locally grown grains and legumes has shown that these relatively simple processing systems can be successfully maintained and operated in developing countries. The process has been demonstrated most extensively on cereal/soy mixtures (70/30 and 80/20) which were cooked in the extruders and ground to a flour that could be easily reconstituted with water to form a gruel used for supplemental feeding. Other LEC applications demonstrated were the production of instant drink bases, soup bases and ready-to-eat cereals.

It was found that the various LEC machines had somewhat different operating ranges but, in general, were best suited for processing

cereal/legume mixtures containing more than 4% fat at moistures ranging between 15-20%. When extrusion-cooked at temperatures over 150°C, the resulting products had a pleasant cooked flavor, low microbiological counts, PERs comparable to casein, and increased nutrient densities as compared to gruels prepared directly from raw grains. With the addition of vitamins and minerals, the resulting products met or exceeded the nutrient standards for supplemental weaning foods published by Codex Alimentarius.

LEC processing systems consist of grain cleaning, grinding and blending equipment to prepare the grains for extrusion. Following extrusion, air cooling, grinding and blending equipment complete the processing system. Packaging has been in consumer-sized (500-1000 g) bags or boxes which were distributed to targeted groups. The cost of processing equipment to produce 0.5-3.0 MT/hr of finished blended food is between $500,000-1.25 million, depending on ingredients used and packaging requirements. The costs of an entire processing plant including land and buildings can vary between 2-3 times the cost of the processing equipment. If the plant is used at maximum capacity, product can be manufactured without profit for about 1.3-1.5 times the raw ingredient costs or for about $0.60-0.70/kg of dry product. These costs are substantially below the cost of similar imported products.

Products made and distributed in developing countries have found acceptance when used in maternal health centers and have been demonstrated to have a beneficial impact on the nutritional status of weaning-aged children. In addition, similar products have been successfully distributed and sold commercially with the level of sales affected by advertising, promotion and the price at the retail outlet.

LEC technology has provided a market for both agricultural commodities and employment opportunities in developing countries. The primary impact has been the growth of soybean production in those countries. Some related employment opportunities have been created for the larger operations such as Sri Lanka.

Another important attribute of LEC technology has been the introduction and development of extrusion technology in these countries. LEC have served as a stimulus to promote extrusion processing and the proliferation of the process to more sophisticated machines and products.

4.2.0 Lessons Learned

Based on the project experiences to date in transferring the LEC technology to developing countries, the lessons learned were:

1. Expand the feasibility analysis in all projects.
2. Increase the market testing of proposed products.
3. Develop and demonstrate a range of products on a pilot scale.
4. Utilize the modular plant design in future installations.
5. Include quality control and product testing capability in-plant.
6. Build project and product consensus in-country.
7. Assure raw material availability and quantities.
8. Increase training opportunities during the project.
9. Increase the technology transfer effort.
10. Increase publicity.

4.2.1 Expanding the Feasibility Analysis in a Project

During the course of the project, circumstances occurred which limited the time and money available to conduct a feasibility analysis prior to making decisions about specific projects. Most analyses were limited to specific food production situations, such as replacing the Title II food products, and rarely examined alternative products and fall-back positions for a project. Feasibility analyses could have helped prevent actions that did not contribute to the project's success and resulted in the conclusion that feasibility studies are important and should be more comprehensive in nature.

The procedures for conducting project feasibility analyses have been refined and demonstrated as part of the Cooperative Agreement. A comprehensive feasibility analysis can be extremely useful to the agencies who are interested in investigating the possibility of embarking into the production of weaning foods or companion products and should be done as the first step in establishing a project. The feasibility study should analyze the need and demand for consumer and weaning food products, the in-country competitive climate, commercial market and distribution system, consumer and test market results as well as define the nutritional characteristics of the product, provide estimates of plant capital and operating costs, a marketing plan, proforma financial analyses, availability of raw materials and capital, and management and personnel capabilities at the proposed site.

4.2.2 Increase the Market Testing of Proposed Products

The original objective of the project was to develop and deploy simple processing systems so that Title II-like products could be produced from local inputs at low cost. This was based on the assumption that Title II products had been used successfully in many developing countries and similar products would therefore have acceptability. This is not necessarily a good assumption and has tended to limit transfer of the technology to governmental agencies and PVOs who have been interested in products for government feeding programs rather than commercial sale. All products which are considered for in-country production use or commercial sales need to be market tested to determine their flexibility. Further work on a broader range of products produced on LEC needs to be performed so that a wider array of products can be market tested and fall-back positions built into the project to avoid complete plant shut downs as experienced in some of the LEC projects.

4.2.3 Develop and Demonstrate a Range of Products on a Pilot Scale

The LEC project to date has focused on weaning foods as products of interest. To expand interest in the technology, a broader range of consumer products such as soup bases, texturized vegetable protein, drink bases, snack items, etc., along with weaning foods and composite flours need to be demonstrated. The best location to develop and demonstrate these products is the pilot plant located at Colorado State University.

Had a range of formulations and product types been developed early on in the project, it may have been possible to enhance the interest in the technology. A range of products can be manufactured by the basic LEC plant

and this versatility would help stimulate greater commercial interest. A multiproduct plant may, in fact, expand the production and distribution of weaning foods since the greater diversity of the plant could improve its profitability and increase commercial interest.

4.2.4 Utilize the Modular Plant Design in Future Installations

Successful Transfer of the LEC technology requires that a single transfer agent be capable of providing all the necessary technology and inputs to the party interested in receiving the technology. Stated another way, the probability for successful technology transfer is greatly diminished if the group from a developing country has to conduct its own study and search out all the necessary information and capability to assemble a plant. The user of the technology wants "one-stop shopping" and prefers the purchase and use of "off the shelf technology." In addition, the user will be attracted to such a transfer agent if it is subsidized so that costs for this element are minimal. Therefore, it is important to have a transfer agent with specialized skills and knowledge who also has project promotion activities.

To reduce costs, time and problems with the installation of LEC plants, the modular plant design should be adopted as the standard for future installations. This approach will work because of the flexibility built into the design and will eliminate problems associated with new and unproven versions. Further, the modular design allows for the preconstruction of the processing section of the plant and disassembly for shipment. Once it arrives on site, the reassembly and commissioning of the

plant at the final plant site with a minimum of skilled labor, time and confusion.

4.2.5 Include Quality Control and Product Testing Capability in Plant

All plants should have the capability for quality control and product testing on-site. Use of testing facilities away from the plant seriously reduces the timeliness of the evaluations that are necessary to assure product consistency and quality. Quality control standards for the product(s) need to be approved by government regulatory agencies.

4.2.6 Build Project and Product Consensus In-Country

For weaning food products to be successful, their acceptance and use must be well defined, understood and supported by a diverse group of professionals. These include medical personnel, nutritionists, public health officials, maternal and child care specialists and food processors. Work needs to be undertaken in all prospective countries where technology transfer is contemplated to inform and gain input from these diverse groups to build consensus for the project and product(s). Once the project is initiated, continued communication efforts need to be emphasized to maintain the support of the user community.

4.2.7 Assure Raw Materials

Careful attention needs to be focused on assuring the availability of the necessary supply of raw materials for the production plant. To the extent possible, they should be grown locally and their production contracted to avoid shortages. When existing procurement and storage

facilities are not adequate to assure a supply of high quality raw ingredients, the processing facility will have to take alternative steps to achieve this status, which may include the construction of large grain and material storage facilities at the plant site.

4.2.8 Training

Training programs for plant management, quality control personnel and factory workers must be part of any new plant start-up. Training materials and manuals have been developed as part of this project. These manuals have been found to be very valuable for this purpose and should continue to be used for this purpose.

Furthermore, the nature of employment in developing countries result in relatively high turnover of personnel. To make this factor less of a problem, retraining programs should be incorporated into the project for the first five years or longer. These programs could be used to solve training problems as well as for troubleshooting specific problems.

4.2.9 Technology Transfer

To achieve successful technology transfer, it is essential that the key in-country contacts have the background and capability to work effectively with the transfer agent. In addition, they need to have the authority to make the necessary arrangements and decisions for the transfer. Continuity of in-country personnel is essential for a timely and successful transfer of the technology.

4.2.10 Publicity

In addition to publication of the findings and documentation developed during the cooperative project, other methods of disseminating results and the potential of the work need to be developed. The extensive literature developed by the project tends to have limited circulation and exposure. The printed materials which have been indexed by international abstracting journals have elicited a large number of inquiries. Articles in trade journals and the LEC Newsletter have also been successful and resulted in dissemination of the project. Documents distributed through AID seem to have little readership, and, therefore, this method of dissemination may have little impact. Expanded contacts would include organizations such as development banks, displays in trade shows and fairs, participation in world congresses, etc.

5.0.0 FOLLOW-UP PROJECTS/RESEARCH

5.1.0 Expand the Pilot Plant

Future successful technology transfer will depend on demonstrating and designing a plant having the ability to process a wide variety of consumer products. To do this effectively, the pilot plant facilities at Colorado State should be expanded to include a broader range of pre- and post-processing equipment such as milling equipment, continuous driers, enrobers and packaging equipment. Working in conjunction with Third World country participants, this pilot plant would be used for developing and testing products which will be acceptable, affordable and directed toward improving the lives of women and children.

5.2.0 Expand Technology Transfer

As part of the initial step in the implementation of successful technology transfer, it is necessary that a transfer team be maintained that can be mobilized to perform comprehensive in-country feasibility studies. The feasibility work needs to be supported by the capability of providing food technology, nutrition, engineering and marketing expertise as required. Support will be required to maintain a core effort to sustain the technology transfer. Without this core project, the necessary staff and expertise will disperse, making future response to inquiries very difficult or impossible.

5.3.0 Demonstrate a Range of Nutritious and Convenient Food Products Which Can Be Produced By Low-cost Food Technologies

Develop ingredient and processing specifications for a variety of generic food products such as soup bases, drink bases, noodles, texturized vegetable protein, convenience foods, snacks, etc., in addition to weaning foods to illustrate the capability and increase interest in the transfer of food processing technologies.

5.4.0 Perform Economic Studies Directed Toward Documenting How Small-scale Food Processing Can Stimulate Third World Development

Since a large fraction of time, effort and income of people in Third World countries is directed toward meeting their food needs, the food system offers the potential for being a significant vehicle for economic development within these countries. Expanded food processing can stimulate demand for alternative crops, justify the adoption of standards and grades,

expand the storage and marketing of commodities, improve distribution and marketing systems, create jobs, expand commercial markets, increase the need for and utility of the public media, etc. A comprehensive study of the role of small-scale food processing plants would document this broad spectrum effect and its potential for economic expansion, a necessary ingredient to the alleviation of Third World poverty.

5.5.0 Examine Smaller-scale Food Processing Technologies

There needs to be a range of food processing technologies that have a wide range of capacity. Small-scale roasters, extruders, expellers, heaters, milling systems, oil presses, etc., need to be evaluated so that these alternatives are more accessible to the user community.

5.6.0 Continue Research on Food Processing

Initial research indicated that extruded sorghum had significantly improved digestibility over other cooking methods and needs to be pursued further. Sorghum is a significant part of the African diet. Improved digestibility could greatly increase the utility of this important cereal crop. More basic research also needs to be done on the processing of oilseeds like amaranth and rape seed, cereals like quinoa and triticale, and pulses to determine how these products could be more effectively cooked and therefore better utilized by humans.

5.7.0 Refugee Foods

Low moisture cooking technologies offer the potential of providing nutritious foods to refugees and displaced persons having limited resources

for the preparation of food. Attention needs to be focused on how food technologies could be directed to the acute needs of these situations with severely restricted facilities.

5.8.0 Alternative Fuels

Renewable forms of energy will become increasingly important as the world's petroleum resources dwindle. Low moisture cooking technologies such as LEC can be used as the first step in the treatment of carbohydrate sources to be fermented into fuel with the potential of making the production of alternative fuels more efficient. Research needs to be conducted to document these benefits.

5.9.0 Animal Feeds

LEC has the potential of serving as an effective means of processing nutritious feed mixtures for improved small animal production, thereby improving the diet of people in the Third World by increasing the supply of lower cost meat products. Feed materials for fish, rabbits, poultry, goats, etc., can be extrusion processed with the result being improved feed efficiency and the use of a wider variety of feed stocks which compete less with human food sources. Research into this potentially interesting utilization of the LEC technology needs to be investigated.

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